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METHOD AND DEVICE FOR MONITORING A BRAKE SYSTEM

Related Art

The present invention relates to a method and a device for detecting a malfunction of a brake system, in particular for detecting a malfunction of the wheel pressure sensor suite of a brake system of a motor vehicle during activation of the brake system as a function of two operating modes; it also relates to a method and a device for operating a system, which controls and/or regulates the functions of a motor vehicle as a function of the detected malfunction, having the features of the independent claims.

In active steering systems, known for instance from DE 38 26 982 A, the brake pressures are able to be detected at the separately controlled wheels of an axle and, sparing a dead zone, their difference ΔP may be utilized at low ΔP to obtain an additional steering angle δ. This considerably increases the driving stability during braking, in particular on uneven roadways.

Summary of the Invention

As mentioned, the present invention describes a method and a device for detecting a malfunction of a brake system of a motor vehicle. At least two operating modes may exist during activation of the brake system. The essence of the present invention is that a malfunction is detected in a first manner when a first operating mode is present and a malfunction is detected in a second manner when a second operating mode is present.

The advantage of the present invention is that possible faults of a brake system, in particular in the wheel pressure sensor

suite of the brake system are able to be detected in each operating mode of the brake system, if possible.

Another variant of the present invention is a method or a device for operating a system which controls and/or regulates the functions of a motor vehicle. For instance, such a system may be a steering system as described in the introduction. According to the present invention, the control and/or regulation is implemented at least as a function of the operating state of a brake system installed in the motor vehicle. In a steering system it may be provided, for instance, that an additional steering angle be adjusted as a function of the operating state of the brake system. The operating state of the brake system is characterized by the variables utilized for operating the brake system, such as the brake pressure in the individual wheel brakes or variables derived therefrom. It may be provided, for example, that the additional steering angle be ascertained as a function of the difference of the brake pressures at the wheels of an axle. The use of an active steering system thus advantageously provides the possibility of utilizing a brake-pressure differential ΔP at the wheel brakes of a wheel axle to control the steering angle of motor vehicles, in particular when braking on an uneven roadway.

The essence of this variant of the present invention is that, in response to a detected malfunction of the brake system, in particular in the wheel pressure sensor suite of the brake system, the dependency on the operating state of the brake system is at least reduced. In the process, the malfunction is detected in a first manner when a first operating mode of the brake system is present, and the malfunction is detected in a second manner when a second operating mode of the brake system prevails.

If a malfunction of the brake system has occurred, in particular of the wheel pressure sensor suite of the brake

system, and this fault were not detected properly, it would affect the functions of the system controlling and/or regulating the motor vehicle. For instance, an incorrectly determined brake-pressure differential would result in a faulty additional steering angle. This invention variant thus has the advantage of at least reducing the effect of a malfunction of the brake system on the regulating or controlling system.

In an advantageous embodiment of the present invention it is provided that the brake system be configured in such a way that braking interventions may be implemented independently of the wish of the vehicle driver. The existence of the first operating mode is detected when no wheel-individual braking intervention takes place during a braking operation. The existence of the second operating mode is detected when a wheel-individual braking intervention takes place during a braking operation. In the monitoring of the brake system according to this implementation, the driver checks during activation of the brake system whether an additional, driver-independent braking intervention is taking place or has taken place within a certain latency period. The differentiation between two existing operating modes thus takes place as a function of the existence of a wheel-individual braking intervention, the query of an intervention by an anti-lock braking system (ABS) being provided, in particular. As is well known, a wheel-individual braking intervention takes place in an anti-lock braking system when the wheel has a tendency to lock up. In the case of a lock-up tendency, the brake pressure is generally kept constant or is reduced. Thus, a fault detection is possible in an advantageous manner during braking with or without wheel-individual braking interventions.

In another development of the present invention, it is provided that the brake pressures at the wheel brakes be modified when the brake system is activated and the vehicle

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has at least one wheel axle and when brake-pressure variables are detected that represent the brake pressure at at least two wheel brakes of an axle. As long as no wheel-individual braking intervention takes place and if a latency period has elapsed after conclusion of a wheel-individual braking intervention, a differential variable representing the difference of the detected wheel-brake pressures is ascertained. The malfunction is detected on the basis of the differential variable exceeding a differential threshold. In particular, it is provided here that the fault detection be performed in a motor vehicle having at least two wheel axles; it being possible for the fault detection to be carried out separately at each wheel axle.

It is particularly advantageous that the differential threshold may assume various values. This makes it possible to achieve a fault detection that is adapted to the particular existing braking situation.

It is particularly advantageous that, once the first operating mode is detected, different values are set for the differential threshold as a result of the rate of increase of the brake pressure, which is averaged using all brake-pressure variables of an axle. The rate of increase may be ascertained by estimation with the aid of a differential quotient, the differential quotient being determined as a function of the difference of two averaged brake-pressure variables detected at different times. To estimate the rate of increase, a maximum value from at least two differential quotients may be utilized in an advantageous manner. This compensates for short-term sudden drops of the gradient without reducing the dynamics of the gradient calculation.

It is possible to use the offset-corrected brake-pressure variables as brake-pressure variables, the offset being estimated from the low-pass filtered brake-pressure signal of each individual wheel brake.

Brake systems usually have a main brake cylinder to generate a brake admission pressure. With a view to fault detection when the second operating mode is present, it is advantageous if the value for the differential threshold is set as a function of

- an admission-pressure variable representing the admission pressure in the main brake cylinder; and
- the rate of increase, in particular of the differential quotient.

One advantage of the present invention is that the fault detection during both operating modes is performed as a function of the dynamic response of the pressure signal at the wheel brakes or the main brake cylinder of the motor vehicle.

In a further development, it is provided that, following a wheel-individual braking intervention, the fault detection be at least modified within a specifiable time duration. In particular, it is provided here that the fault detection be suspended within a specifiable time duration (latency period) following a wheel-individual braking intervention.

Further advantages result from the following description of exemplary embodiments and from the dependent claims.

Brief Description of the Drawing

The figures show:

Figure 1 in a schematic illustration, the recording of the operating variables of the brake system for fault detection and the forwarding of a fault to a controlling and/or regulating system of the motor vehicle;

Figure 2a the procedure for differentiating the two operating modes in which the fault detection is active in a driver-initiated braking intervention;

Figure 2b the calculation of the offset-corrected pressure signals; and

Figures 3 and 4 the flow charts permitting a preferred detection of the malfunction in the two operating modes.

Exemplary Embodiments

Figure 1 illustrates an exemplary embodiment for monitoring a brake system. In the process, pressure signals p_n of the wheel brakes at each individual axle are transmitted to block 10, the pressure signals representing the brake pressure. For reasons of clarity, however, only pressure signals p_{fr} (20) and p_{fl} (22) of an individual axle having two wheel brakes have been included in Figure 1. p_{fr} represents the brake-pressure signal in the front right wheel brake, and p_{fl} the brake-pressure signal in the front left wheel brake. However, this may easily be expanded to a plurality of axles and to additional wheel brakes per axle. In addition to the pressure signals of the wheel brakes, block 10 is provided with pressure signal p_a (30) for the admission pressure in the main cylinder.

Furthermore, state identifiers of braking interventions in the form of flags are forwarded to block 10. In this context, unset flag 0 corresponds to the operation of the brake system without braking intervention, and set flat 1 corresponds to the occurrence of a braking intervention. Different flags are defined so as to differentiate the various possible braking interventions, these being supplied to block 10. For instance, the driver-initiated activation of the brake system is represented by flag F_B, the intervention in the brake system

by an anti-lock braking system (ABS) by flag F_{ABS}, the intervention by a traction control system (TCS) by flag F_{TCS}, and the intervention by a general vehicle control by the flag F_C. Moreover, clock generator t (48) makes it possible for block 10 to determine time difference Δt with respect to the most recent braking intervention. This is accomplished in that the time measurement is started by the change of a flag from 1 to 0.

With the aid of the read-in values 20 through 46 as well as time measurement Δt in connection with clock generator t (48), a malfunction of the brake system of a motor vehicle is detected in block 10 as illustrated in Figure 2. Because of the detected malfunction (signal F), the controlling and/or regulating function of a system for operating a motor vehicle is modified in a second block 50. Block 50 may represent a steering system, for example, as mentioned in the introduction, which generates an additional steering angle as a function of the operating state of the brake system.

Figure 2 shows an exemplary embodiment of a malfunction detection of a brake system of a motor vehicle. The sketched program is started at specified cycles throughout the entire operation. The flow diagram essentially illustrates the situation in the detection of two different operating modes in a driver-dependent braking intervention.

For this purpose, the flags for a driver-dependent braking intervention -- F_B -- and for a driver-independent braking intervention such as an anti-lock braking system (ABS) -- F_{ABS} --, a traction control system (TCS) -- F_{TCS} -- or a general vehicle control -- F_C -- are first queried in step 100. In addition, time difference Δt, which has elapsed since the most recent intervention of a driver-independent braking intervention, is determined. In the following step 105, pressure signals p_n of each individual wheel brake are read in. In step 110, each individual pressure signal is monitored for

compliance with the measuring range specified by the particular type of design of the associated pressure sensor. If one of the pressure signals is outside the measuring range, a fault (signal F/Figure 1) is detected. Subsequently, in step 115, the stored value of the offset from the last program cycle is used as estimated value for the pressure offset. Using this pressure offset, the offset-corrected pressure signals $p_{corr,n}$ are thus determined.

In the following step 120, it is ascertained whether a possibly available traction control system is regulating or controlling the drive slip of a wheel. Processing of the program will be continued only if the traction control system (TCS) is not active ($F_{TCS}=0$) and a certain latency period t_{TCS} has elapsed since the last activation of the traction control system (TCS) ($\Delta>t_{TCS}$). In step 125, the braking intervention of a vehicle controller F_C is checked in general. The program is continued if a vehicle controller is not active ($F_C=0$) and a certain latency period t_C has elapsed since the last intervention by a vehicle controller ($\Delta t>t_C$).

The following step 130 checks the activation of the brake system by the driver of the motor vehicle on the basis of set flag F_B for the driver-dependent braking intervention. If the driver has not initiated any braking intervention ($F_B=0$) and if a specific latency period t_B has elapsed since the last driver-initiated activation of the brake system ($\Delta t>t_R$), the offset calculation will be performed in step 135. To estimate the offset of the pressure signals, each pressure signal is individually conducted via a low pass filter. The filter is stopped as soon as a driver-activated braking or a braking intervention takes place. The filtering is resumed when a specified latency time has elapsed since the most recent driver-activated braking or the last braking intervention. In step 140, the ascertained absolute amounts of the offset values are checked with respect to an exceedance of an offset threshold. If the offset threshold has been exceeded, a fault

(signal F/Figure 1) is detected. If no fault has occurred, a zero-value monitoring of the wheel-brake pressures is carried out in step 145. This zero-value monitoring is based on the fact that all wheel-brake pressures (with the exception of slight measuring errors) must be equal to zero if no driver-activated braking and no braking intervention are taking place. Zero-value faults (signal F/Figure 1) are detected when the absolute amounts of the corrected pressures exceed a zero-value threshold and no driver-activated braking and no braking intervention take place at the same time or have taken place within a latency period. If no fault is detected, the program is terminated and restarted with the next polling cycle.

If the activation of the brake system by the driver of the motor vehicle has been detected in step 130 based on set flag FB (F_B=1) or if the elapsed time since the last driver-activated braking intervention is below latency period t_B, it is checked in step 160 whether a braking intervention by an anti-lock braking system (ABS) is taking place (Flag F_{ABS}) and more than a specific latency period t_{ABS} has elapsed since the last intervention of an anti-lock braking system. On the basis of this check, the subsequent fault detection is subdivided into operating mode I (step 170) and II (step 180). Operating mode I (step 170) is run through in the event that $F_{ABS} = 0$ and ($\Delta t > t_{ABS}$), i.e., the driver-dependent braking intervention occurs without any additional brake regulation by the anti-lock braking system (ABS) and the latency period for the intervention of an anti-lock braking system (ABS) is exceeded. On the other hand, operating mode II (step 180) with $F_{ABS} = 1$ is run through when the driver-dependent braking intervention occurs with an additional brake regulation by the anti-lock braking system (ABS) or the latency period for the intervention of an anti-lock braking system (ABS) has not yet been exceeded.

Figure 3 shows a detailed representation of the fault detection of operating mode I (170 of Figure 2), i.e., in the event that no wheel-individual braking interventions occur independently of the driver, in particular by the anti-lock braking system (ABS). The flow chart illustrates the situation with the fault detection being caused by the exceeding of pressure differences of the brake pressures at the wheel brakes of a motor vehicle axle. A corresponding program is run through for the additional axles of the motor vehicle or the sketched program is consecutively run through for each axle.

In first step 200, brake-pressure variable Δp_{corr} is determined from the offset-corrected wheel-brake pressures (115) as the pressure differential of the brake pressures at the wheel brakes of a wheel axle. In step 205, the averaged brake pressures of all wheel brakes N is determined from the offset-corrected brake-pressure variables according to the equation

$$p_m = \frac{1}{N}\sum_{n=1}^{N} p_{corr,n}$$

An estimation of the rate of increase of the averaged brake-pressure variables takes place in step 210 via the differential quotient

$$gp_m = \frac{p_m[k] - p_m[k-1]}{T}$$

k and k-1 representing two consecutive points in time at which the averaged brake pressure is determined, and T representing the time differential between these two instants. In step 215, the absolute amount of differential quotient gp_m is subsequently formed and, to compensate for a short-term sudden drop according to

$$gp\max = \max\{|gp_m[k]|, |gp_m[k-1]|\}$$

maximum value gp_{max} is determined over at least two calculations of differential quotient gp_m. In step 220, differential quotient gp_{max} resulting in the process is compared to a lower value gp_0 that is typical for the brake system. When value gp_0 has or has not been attained, the permissible threshold value for brake-pressure differential Δp_{all} at the wheel brakes, in step 235, is set to a lower specified value $\Delta p_{all,0}$, this value depending on the type of brake system. In the event that differential quotient gp_{max} is greater than gp_0, in step 225, differential quotient gp_{max} is compared to an upper value gp_1, which is typical for the brake system. If this value gp_1 has or has not been attained, the permissible threshold value for brake-pressure differential Δp_{all} at the wheel brakes, in step 240, is set to a value according to the equation

$$\Delta p_{all} = \Delta p_{all,0} + \frac{\Delta p_{all,1} - \Delta p_{all,0}}{gp_1 - gp_0} gp_{max}$$

$\Delta p_{all,0}$ and $\Delta p_{all,1}$ being two values that are specified on the basis of the brake system type. In step 230, the case will finally be examined where differential quotient gp_{max} is above value gp_1. In step 245, the allowed threshold value for brake-pressure differential Δp_{all} at the wheel brakes is then set to an upper specified value $\Delta p_{all.1}$ as a function of the type of brake system. If in step 250 the ascertained variable Δp_{corr} from step 200 for the brake-pressure differential of the wheel brakes exceeds ascertained allowed threshold value Δp_{all} from steps 235 through 245 at at least one axle, a fault (signal F/Figure 1) is detected. Otherwise, the program is set back and restarted with the next polling cycle.

Figure 4 shows a detailed representation of the fault detection in operating mode II (180 of Figure 2), i.e., in the event that a wheel-individual braking intervention occurs, in particular an intervention by the anti-lock braking system (ABS) during a driver-activated braking procedure. The flow chart illustrates the situation in a fault detection caused by the exceeding of pressure differences of the brake pressures at the wheel brakes of a motor vehicle axle. For the other axles of the motor vehicle a corresponding program is run through or the sketched program is consecutively run through for each axle.

In step 300, as in step 200 (Figure 2), brake-pressure variable Δp_{corr} is determined from the offset-corrected wheel-brake pressures as pressure differential of the brake pressures at the wheel brakes of a wheel axle. Furthermore, pressure signal p_a for the admission pressure in the main brake cylinder of the brake system and differential quotient gp_m are recorded as measure for the dynamics of the averaged brake pressure at the wheel brakes of an axle. Subsequently, in step 310, it is ascertained whether the pressure signal for the admission pressure falls below a specified threshold value $\Delta p_{ABS,0}$ and the averaged brake pressure at the wheel brakes of an axle simultaneously drops in the form of a negative differential gradient. If this is the case, in step 320, permissible threshold value $\Delta p_{ABS,s}$ for the pressure differential is set to specified limit value $\Delta p_{ABS,0}$. If one of the conditions in step 310 is not given, allowed threshold value $\Delta p_{ABS,s}$ for the pressure differential is set to equal the pressure signal of the admission pressure in step 330. If recorded brake-pressure differential Δp_{corr} from step 300 exceeds ascertained threshold value $\Delta p_{ABS,s'}$, a fault (signal F/Figure 1) is detected in step 340. Otherwise, the program will be set back and restarted with the next polling cycle.

In summary, a method and a device for monitoring a brake system, in particular a wheel-pressure sensor suite of a brake

system of a motor vehicle, are provided in which the fault detection (block 10) is implemented on the basis of a differential threshold (250, 340) being exceeded by a signal, which is representative for the difference in the brake pressures at the individual wheel brakes of a wheel axle. In the process, the differential threshold is set as a function of the averaged rate of increase of the individual pressures at the wheel brakes (235 to 245, 320 to 330). The fault detection is implemented on the basis of a model, which takes the instantaneous operating state of the brake system into account.